AN INVESTIGATION INTO THE COMPATIBILITY OF SOME IRREVERSIBLE HYDROCOLLOID IMPRESSION MATERIALS AND DENTAL GYPSUM PRODUCTS

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Submitted in partial fulfilment of the requirements for the degree of M.Sc.(Dent) in the department of Prosthetics of the Faculty of Dentistry of the University of the Western Cape.

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DECLARATION

I declare "An investigation into the compatibility of some irreversible hydrocolloid impression materials and dental gypsum products" is my own work and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.

signed................

Dr C P Owen

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1. IRREVERSIBLE HYDROCOLLOIDS

1,1 INTRODUCTION

A mucous extraction from brown seaweed (Lammeria Clousteni) has been known for almost a hundred years. Originally named 'algin', it's use as a dental impression material was first patented by a chemist, S.William Wilding in 1941. (Phillips 1973).

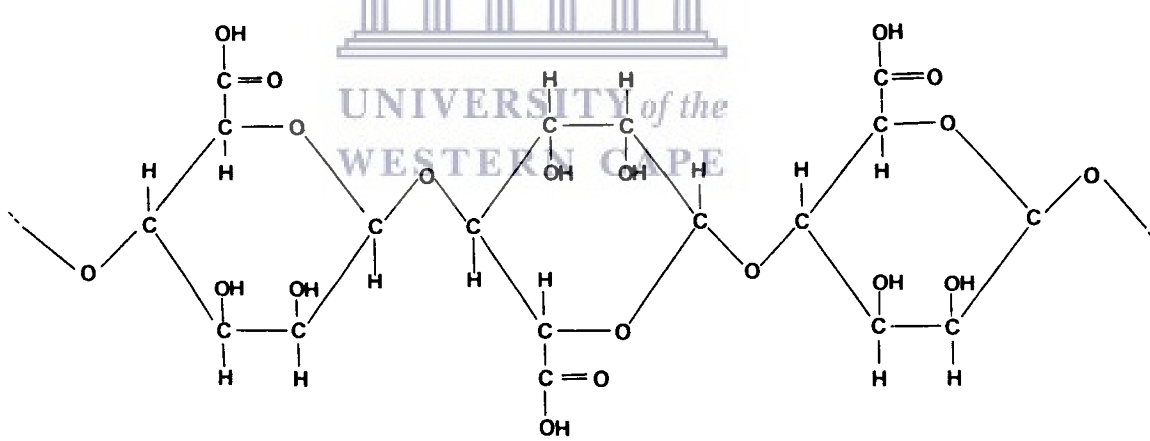
War-time difficulty in obtaining the more commonly used and popular agar impression materials resulted in the improvement in the algin material to become the irreversible hydrocolloid material known as alginate.

In 1943, Schoonover and Dickson stated that the basic ingredients of these materials are a soluble alginate (sodium, potassium, or ammonium alginate), inert filler materials (calcium carbonate, magnesium oxide, calcium sulphate, zinc oxide, etc.) and a small amount of a soluble phosphate, usually trisodium or tripotassium phosphate.

Buchan and Peggie (1966) investigated the effects of some of these ingredients on the handling characteristics and physical properties of a commercial alginate available at the time. They found that high proportions of the alginate salt promoted improved resilience; that calcium sulphate dihydrate with or without the hemihydrate produced a more acceptable impression material than the hemihydrate alone; that individual fillers exerted a profound effect on handling characteristics and gel properties; and that trisodium phosphate in excess lengthened the setting time, detracted from the elastic properties, and reduced the hardness of the impression.

1,2 CHEMISTRY, COMPOSITION AND STRUCTURE [Mainly from Phillips and Combe, 1977]

In current alginate impression materials, sodium and triethanol amine alginate are used, the only other soluble salts being those obtained with potassium and ammonium. The salts are held to be linear polymers of anhydro-beta-d-mannuronic acid. The structural formula is as follows:



When the alginic acid is changed to a soluble salt such as sodium alginate, the cation is attached at a carboxyl group to form an ester or salt. The molecular weight of the alginate salts varies considerably, depending on how many molecules are joined on a long chain. (For sodium alginate a figure of 185,000 has been given).

When mixed with water the soluble alginates form a sol similar to the agar sol. To chemically induce gelation, an insoluble salt must be formed. When this is formed by the reaction of sodium alginate in solution with a calcium salt, for example, the calcium ion may replace the sodium ions in two adjacent molecules to produce cross-linking between the molecules. As the reaction progresses, a cross-linked molecular complex or polymer network forms which constitutes the 'brush-heap' gel structure, and the fibrils are thus held by primary bonds. The reaction can be represented by the formula:

$$Na_nAlg + {}^{n}/2\ CaSO_4 \longrightarrow {}^{n}/2\ Na_2SO_4 + Ca^{n}/2Alg$$

The cross-linkage between fibrils via calcium atoms prevents the movement of one fibril over another and thus resists permanent deformation of the gel.

The source of calcium ions is calcium sulphate, which provides calcium ions at a fairly slow rate so that only the outer layer of each particle of sodium alginate dissolves. However, the above reaction will actually occur at a rate greater than is practical for use as an impression material, and hence a retarder is added. It's purpose is to reduce the number of calcium ions available for reaction, by selectively removing them in a reaction whose course and end product will not alter the properties of the final gel. Trisodium phosphate, sodium phosphate and tetrasodium pyrophosphate have all been used.

The retarding reaction can be represented as:

$$2Na_3PO_4 + 3CaSO_4 \longrightarrow Ca_3(PO_4)_2 + 3Na_2SO_4$$

This reaction will occur preferentially until the trisodium phosphate is used up, when the remaining calcium ions will react with the alginate to produce the gel.

The final gel structure will be a brush heap of a calcium alginate fibril network enclosing unreacted sodium alginate sol, excess water, reaction by-products and filler particles. Filler particles are mainly present to increase the strength and stiffness of the gel; to produce a smooth texture and firm surface; and to aid in dispersing the alginate powder particles in the water. As stated above, Buchan and Peggie (1966) found that fillers can have a profound effect on handling characteristics and gel properties.

Modern materials now use very different chemicals than those in the early alginates, but the principles of their inclusion are still the same, and calcium sulphate still appears to be used as the reactor.

2. DENTAL GYPSUM PRODUCTS

2,1 INTRODUCTION

Gypsum is a mineral that is widely distributed in nature and mined in various parts of the world. Different forms of it have been used by man for a long time (the biblical 'alabaster' is presumed to be a form of gypsum), and plaster has been recorded for use in making dental casts since 1756. (A.D.A., 1976. Phillips, 1973). In 1884 Le Chatelier proposed a theory for the hardening of plaster, amd many workers since have contributed to present knowledge of its chemistry (Fairhurst 1960).

2,2 CHEMISTRY AND STRUCTURE [from Phillips 1973, Combe 1977]

The basic ingredient for plaster, dental stone and high strength dental stone, and gypsum bonded investments is a hemi-hydrate of calcium sulphate. The main differences between the basic powders lie with variations in the size, shape and porosity of the particles produced by different methods of manufacture.
The hydrates of calcium sulphate are summarised in Table 1.

2,2.1 Dental Products

Dental plaster has **calcined** calcium sulphate hemihydrate as its main constituent together with chemicals to control the setting time. Model and die materials are based on **autoclaved** calcium sulphate hemihydrate plus additives to adjust the setting time, and colouring pigments.

TABLE I: Hydrates of calcium sulphate

Mineral source → calcium sulphate dihydrate ← By-product of other industries

calcium sulphate dihydrate, gypsum, $CaSO_4,H_2O$

↓ heat in an open vessel, 120°C	↓ heat in autoclave under steam pressure, 120–130°	↓ heat ground gypsum in water with small quantity of organic acid or salt, in an autoclave, 140°C	↓ heat in boiling 30% solution of calcium choride or magnesium chloride
↓ calcined cacium sulphate hemihydrate (sometimes called the 'β-hemihydrate') $(CaSO_4)_2,H_2O$	↓ autoclaved calcium sulphate hemihydrate (sometimes called 'hydrocal' or α-hemihydrate') $(CaSO_4)_2,H_2O$	↓ autoclaved calcium sulphate hemihydrate (sometimes called 'α-hemihydrate') $(CaSO_4)_2,H_2O$	↓ calcium sulphate hemihydrate (sometimes called 'densite'; similar to autoclaved material $(CaSO_4),H_2O$)

heat < 200°C ↓

hexagonal calcium sulphate
(sometimes called 'soluble anhydrate')
$CaSO_4$

heat > 200°C ↓

orthorhombic calcium sulphate
(sometimes called 'insoluble anhydrite')
$CaSO_4$

[from Combe, 1977]

2,2.2 Setting reactions

Addition of water to the hemihydrate causes the formation of the dihydrate, which is thus the reverse reaction whereby the hemihydrate is formed:

$$(CaSO_4)_2.H_2O \; + \; 3H_2O \; \longrightarrow \; 2CaSO_4.2H_2O \; + \; Heat$$

The precise nature of the setting reaction has still not satisfactorily been elucidated but has been summarised as follows:

After mixing the hemihydrate with water, some dissolves, giving Ca^{2+} and SO_4^{2-} ions. At normal room temperature, the solubility of hemihydrate is approximately 0,8% and of the dihydrate, 0,2%; the dissolved hemihydrate thus forms the dihydrate in solution, which is then supersaturated. Crystal growth of the dihydrate occurs from this solution, on nuclei of crystallisation which may be crystals of gypsum initially present as an impurity; diffusion of the Ca^{2+} and SO_4^{2-} ions to these nuclei takes place. The crystals formed are characteristically needle-like clusters ('spherulites'); the final rigid structure of the set gypsum is the result of the intermeshing and entangling of these crystals.

If the equivalent volumes of the hemihydrate, water and the reaction product are compared, a calculated volume contraction of 7,11% occurs during the setting. However, setting **expansion** is actually observed, and this apparent paradox is accounted for by consideration of the mechanism of crystallisation, together with the fact that excess water is required to produce a workable consistency. Crystal impingement and movement results in the production of micropores so that the reaction product is greater in **external** volume but less in **crystalline** volume.

The final structure immediately after setting is one of interlocking crystals between which are micropores and pores containing the excess water required for mixing. On drying, the excess water is lost. The greater the water/powder ratio, the greater the porosity, as there will have been fewer nuclei of crystallisation and thus less intermeshing of the gypsum crystals.

2,2.3 Additives

There is a general relationship between the type of chemical or material and its effect on the setting time. Retarders absorb onto the surface of the hemihydrate particles or the growing gypsum crystals and so reduce the dissolution of the hemihydrate or the crystallisation of the gypsum. Accelerators increase the latter processes.

Chemical accelerators and retarders also generally reduce the setting expansion. The theory of such effects is still obscure, but may be related to changes which they produce in the shape of the crystals formed.

Sodium chloride, potassium sulphate,and sodium potassium tartrate in 2% solutions are all known to reduce setting time, compressive strength and linear expansion. One of the most effective retarders is borax in any concentration, as calcium borate forms which deposits on the nuclei of crystallisation ('poisoning'), effectively reducing the rate of crystallisation. Poisoning of nuclei also occurs in the presence of many colloids.

3. THE INTERACTION BETWEEN ALGINATE AND DENTAL GYPSUM

Since a hydrocolloid gel consists predominantly of water loosely enclosed within the gel fibrils, this water will evaporate if the gel is exposed to an unsaturated atmosphere. This loss of water may be accompanied by an exudation in a process known as syneresis, which, however, may occur without the simultaneous loss of water. The syneretic exudate consists of some of the more soluble constituents of the gel.
As stated previously, colloidal gels are known to be retarders of gypsum products, and thus the syneretic exudate from an alginate gel will have an adverse effect on the setting reaction of the dental plaster or stone in contact with it. This was recognised early on in the use of these materials. Skinner and Pomes in 1946 reasoned that if an impervious film of some nature can be formed over the surface of the impression, no molecular change can take place between the impression material and the atmosphere, with no resultant syneresis. Such a film can be produced by soaking the formed gel in any metallic salt that will produce an insoluble gel. The 'fixing' solution should preferably contain some type of accelerator for gypsum so that any retarding effects of the products of syneresis is overcome, and the surface of the cast will be unaffected. Skinner and Pomes (1946) investigated various fixing solutions with this point in mind, and also to ensure that they would produce no dimensional change. They could recommend no particular solution or concentration as being the best, but concluded that copper sulphate was

contraindicated since it produced a contraction of the gel. More importantly, they found that the **concentration** of the fixing solution affected the dimensionl stability of the impression material investigated, within certain limits. With some of the solutions used, (e.g. magnesium sulphate, zinc sulphate), unknown phenomena took place, but it can be shown that with potassium sulphate, the effect can be related to osmotic pressure between the solution concentration and the gel. One of the original products of reaction between a soluble potassium alginate and calcium sulphate is potassium sulphate in solution. This is probably the dispersion medium of the gel and its osmotic pressure will largely determine the eventual stability of the gel. Consequently if the fixing solution of potassium sulphate has the same osmotic pressure no change in dimension will occur. However, by the same token, if it is present in excess, the original reaction may be reversed and the impression will disintegrate. A solution of 2% or less has been found not to cause this reversal or disintegration, provided immersion of the impression does not exceed 10-15 minutes.

In 1965, Skinner and Gordon investigated the surface hardness of dies produced by both irreversible and reversible hydrocolloid impressions. They found that the surface hardness of model **plaster** was not affected by hydrocolloid gels, and that fixing solutions improved the surface hardness of **stone** dies. They advised that the optimum composition and concentration of the hardening solution may vary from one commercial hydrocolloid to another, and therefore that it should be specified by the manufacturer.

By 1959, however, manufacturers seem not to have heeded such advice, as tests carried out by Hosoda and Fusayama showed that all unfixed alginate impressions produced much worse model surfaces than those produced by fixed impressions. All the manufacturers of the five alginates they tested directed that no fixing was necessary. The fixing solution advised by these authors was 1-2% zinc sulphate.

Smith and Fairhurst (1962), found that gypsum cast against alginate exhibited high concentrations of residual hemihydrate in the surface as compared with specimens cast against glass or a freshly ground gypsum surface. This residual hemihydrate was reduced to some extent by the use of a potassium sulphate fixing solution which did not, however, overcome the retarding action of most of the hydrocolloids on the surfaces of the dental stones used in the study.

In an investigation of available alginates published in Britain in 1963, Wilson and Smith stated that fixing solutions were not considered necessary and were not recommended by any of the manufacturers of the alginates used. However,they found that the condition of the cast surface of the stone ('Kaffir D' was used) was considerably affected by the impression material: some had a satisfactory surface, whilst others were very chalky and soft.

An Australian study in 1965 (Chong, Chong, and Docking) again illustrated that the phenomenon of incompatibility of some alginates and gypsum products was still quite real, but failed to clarify the problem. No fixing solutions were used in this study, nor were they in the study by Morrow et al (1971) which again showed up incompatibility of certain alginate/gypsum combinations. This interaction between brands has also been confirmed by Öwall and Nilner (1973).

It can be seen from the above that the problem of imcompatibility of some alginates and some gypsum products has not really been solved, nor have the precise mechanisms been elucidated whereby some combinations achieve better results than others. It obviously has to do with the composition of each material used, but to discover what constituents create the compatibility or incompatibility is extremely difficult.

Civjan, Huget and de Simon (1972), investigating the effect of various storage media on alginates suggested that some of the syneretic effects could be explained in terms of the Hofmeister series. The coagulating effect of a given salt depends on the nature of its ions, and the salts of a given metal, for instance, can be arranged in order of their decreasing ability to cause precipitation of lyophilic substances from colloidal suspension. The resulting arrangement is called the Hofmeister series or the lyotropic series; the order of anions, for a given cation, is

$$SO_4^{-2} > C_2H_3O_2^- > Cl^- > NO_3^- > ClO_3^- > I^- > CNS^-,$$

while that of cations, which have a smaller influence than anions, is

$$Mg^{+2} > Ca^{+2} > Sr^{+2} > Ba^{+2} > Li^{+} > Na^{+} > K^{+}.$$

(Glasstone and Lewis, 1968)

Phillips (1973) states that whenever sodium or potassium zinc fluoride, sodium fluosilicate, or sodium fluotitanate are the fluorides present in the alginate, the use of a hardening solution of zinc sulphate will have little or no benefit, but that it should be used when other double fluorides are present. No evidence for this statement is presented.

In each part of the world different alginate and gypsum materials are manufactured or are available. The last study published on compatibility was in 1973 in Sweeden (Öwall and Nilner), and only two of the materials used (Zelgan, Vel-Mix) are available in South Africa at this time. The purpose of this study is primarily therefore to discover the compatible and incompatible combinations of alginates and dental plasters and stones available, and to investigate the use of readily available fixing solutions on such combinations.

4. THE ASSESMENT OF COMPATIBILITY

4,1 METHODS USED AND DEVELOPMENT OF STANDARDISATION

In 1959, Hosoda and Fusayama quoted an earlier paper by Miller et al who used a fine line 0.040 mm wide cut on an original model surface, and suggested that an impression failing to reproduce this wide a line on a stone model might be inadequate for an indirect technique for inlays or crowns. Hosoda and Fusayama were interested in using alginates to produce as good a surface as the mercaptan-based materials in use at that time. They modified Miller's method and used lines of varying widths cut on a brass plate with a steel cutter whose sides met at 90°. The line widths were 0,008; 0,010; 0,020; 0,030; and 0,040 mm in width. A microscope which magnified 40 times and an oblique illumination were used to examine the reproduced lines and surfaces of the stone models.

Ayers and co-workers (1960) developed a different detail duplication test to evaluate elastomeric impression materials. Their test models were stainless steel cylinders on which were placed a pattern of Knoop indentations, each pattern consisting of three scales of seven indentations, whose dimensions varied from a length of 0,034 mm and depth of 0,002 mm to a length of 0,422 mm and a depth of 0,028 mm. The numbers of indentations on each scale reproduced by the various materials were then quantified.

Chong _et al_ (1965) mentioned that the Australian Standard T.15 for alginates had a gypsum compatibility test that required the plaster or stone to be poured into an impression taken of a metal model. They felt, however, that many products that passed this test still left much to be desired clinicaly. Therefore they evaluated casts poured into impressions that had been taken in the mouth in the normal way. Evaluation of surface quality was on a scale of a half to four, in intervals of a half.

In 1968, the Council on Dental Materials and Devices of the American Dental Association accepted Specification Number 18 for Alginate Impression Materials (A.D.A. 1968). This, briefly, requires the impression material to impart a smooth non-chalky surface to, and separate cleanly from, a gypsum cast made from unmodified alpha calcium sulphate hemihydrate. The cast poured against the material must reproduce, over a 30 mm length, a line 0,075 mm wide having an included angle of 60°, scribed on a stainless steel test block. The gypsum itself must be capable of reproducing a similar line, 0,050 mm wide, when allowed to harden against the test block. Evaluation is carried out under low-angle illumination without magnification.

Morrow and colleagues (1971) tested the compatibility of selected alginates and selected dental stones. They used alginates that had been certified as meeting the American Dental Association's specification No.18, and used that specification as the basis for their tests, with some modification of actual procedure. They found that all casts reproduced the 0.075 mm line satisfactorily, but that the surfaces of the casts varied. The 0.025 mm line was used as the criterion and observation was made under magnifiction (X10) with reproducible low-angle illumination. This procedure created the required discrimination and enabled the authors to show differences in compatibility between the various materials tested.

Öwall and Nilner (1973) departed from the A.D.A.-type standard as they felt that only a few investigations had dealt with the ability of model materials to fill out impressions of edges and corners. The stainless steel master they used was a truncated cone-shaped model with a serrated top turned as a section of a screw with nine 60° threads. Handling of materials differed markedly from the A.D.A. specification. A measuring microscope was used to evaluate results.

In 1978, ISO (the International Organisation for Standardisation) published their revised version of Standard ISO 1563-1978(E) for alginate dental impression material. This requires the reproduction of lines of varying widths cut in a stainless steel block, and no studies have as yet been published utilising this standard. As this forms the basis for the method used for assesing compatibiliy in this study, it is described fully in the next section.

5. MATERIALS USED

The alginate and gypsum materials were donated ex stock from dental supply companies, and are listed in Tables II and III, in alphabetical order. Table III also shows the recommended and used water/powder ratios.

In addition, as stated, the poly-ether material Impregum (ESPE, Germany) and the poly-sulphide material Permlastic Regular (Kerr, U.S.A.) were used in Phase 1. (see later).

Chemically pure potassium sulphate and alum were purchased in powder form and made into solution by the addition of distilled water.

The 50/50 combination of Plaster of Paris and Yellow stone was made by mixing equal quantities of each by weight, and then determining the water/powder ratio as for the other products. (see later). This combination was used because it was felt that it is frequently used by dental laboratories, with or without the knowledge of the dental practitioner.

The standards to which the manufacturers claim compliance for their alginates are listed in Table IV, together with recommended gypsum products.

TABLE II ALGINATES USED

ALGINATE	MANUFACTURER	BATCH NO.
Blueprint Rapid	De Trey, England	AJ75 81/09
Colourgel	Wright Dental, Scotland	5792
G-C Fast-set Technicol	G-C Dental, Japan	2FC17
G-C Vericol Aroma (pink)	G-C Dental, Japan	2FL29
Kalginate, fast-set	Lee-Smith, U S A	004018
Kerr Alginate, fast-set	Kerr, U S A	13244
S S White, normal set	S S White, England	011108
Zelgan Green, fast-set	De Trey, England	ZB10
Zelgan Pink, normal set	De Trey, England	YK13

TABLE III Gypsum products

GYPSUM PRODUCT	MANUFACTURER	WATER/POWDER RATIO Recommended	Used
E P 1	De Trey, England	0,28-0.32	0,31
Yellow stone ('Kaffir D')	British Gypsum Co.	0,30	0.29
Kerr Ortho stone	Kerr, U S A	0,36-0.38	0,36
Peach stone	Columbus Dental, U S A	0,24	0,24
Plaster of Paris	British Gypsum Co.	0,5	0.5
Vel-Mix	Kerr, U S A	0.22-0.25	0.24
50/50 mixture of Plaster of Paris and Yellow stone			o,35

TABLE IV Standards manufacturers claim compliance with, and recommended gypsum products

ALGINATE	STANDARDS	GYPSUM PRODUCTS
Blueprint	I S O 1563 Class B Type I	Calestone; E P 1; Alpha Dur; Moldano
Colourgel	B S 4269; A D A 18; A S 1282	None stated
G-C Fast-set Technicol	A D A 18; I S O 1563	None stated
G-C Vericol Aroma	A D A 18; I S O 1563	G-C new plastone
Kalginate	A D A 18 (certified); I S O 1563	G-C new plastone
Kerr Alginate	A D A 18 (certified)	None stated
Key-to-Alginate	A D A 18 (certified)	None stated
S S White	B S 4269	None stated
Zelgan Green	I S O 1563 Class B Type I	Calestone; E P 1; Alpha Dur
Zelgan Pink	not stated	

6. METHODS

6,1 INTRODUCTION

The International Standard (ISO 1563-1978(E)) for alginate dental impression materials specifies a test for compatibility with gypsum and detail reproduction utilising a ruled test block and moulds. The alginates are classified according to their ability to reproduce lines of varying widths on gypsum casts, and must impart a smooth surface to, and separate cleanly from, such casts.

6,2 TEST BLOCK, MOULDS AND CLASSIFICATION REQUIREMENTS

The ISO 1563 specification for the test blocks and moulds is appended (page 24). The test block and moulds B and D were obtained from Oslo, Norway, and duplicates of moulds B and D were then made locally. (see Figs. 1 to 4, pages 25,26)

Classification is based on clinical application and setting time as follows:

Type I: fast setting - stated setting time of 3 min or less at 32°C

Type II: normal setting - stated setting time of more than 3 min and less than 5 min at 32°C

Class A: suitable for crown or inlay impressions

Class B: suitable for denture impressions

Class C: suitable for study models and individual tray impressions

Classes A,B,C, are designated according to viscosity and permanent deformation tests as well as detail reproduction. As this study is only concerned with the latter, the requirement of this test only is stated as follows:

Class A: reproduce line width 0,020 mm

Class B: reproduce line width 0,050 mm

Class C: reproduce line width 0,075 mm

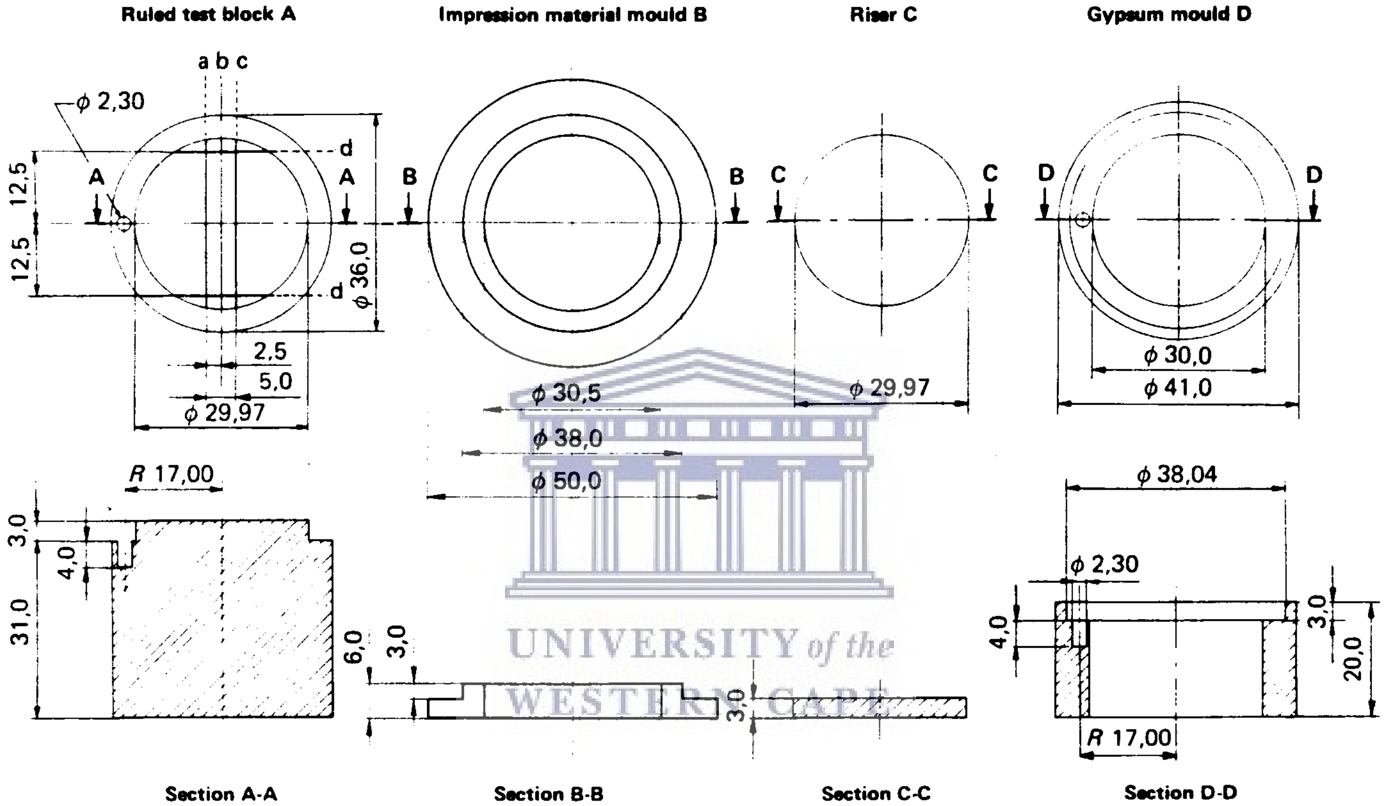
Gypsum: The Standard specifies that the following shall be recommended:

For Class A alginates: at least two brands of alpha modified gypsum (characterised by a water/powder ratio of about 0,23) and one brand of alpha gypsum (characterised by a water/powder ratio of 0,3).

For Class B alginates: at least one brand of alpha modified gypsum and two brands of alpha gypsum.

For Class C alginates: at least two brands of alpha gypsum.

Dimensions in millimetres



Ruled test block for determining compatibility with gypsum and detail reproduction

Specifications

Materials

Ruled block :
Austenitic steel for castings

Impression material mould :
Austenitic stainless free-cutting steel

All other parts :
Brass

Surface finish

Ruled surface : 0,1 µm R_a max., scratch-free.

All other surfaces : 4,0 µm R_a max., unless otherwise specified

Tolerances : 0,1 mm to one decimal place

Ruled test block A

*Ruled line widths** (µm)

Line a : 50 ± 8

Line b : 20 ± 4

Line c : 75 ± 8

Line d : 75 ± 8

* All lines have 90° included angle.

FIG.1. Test block with grooves a,b,c as shown

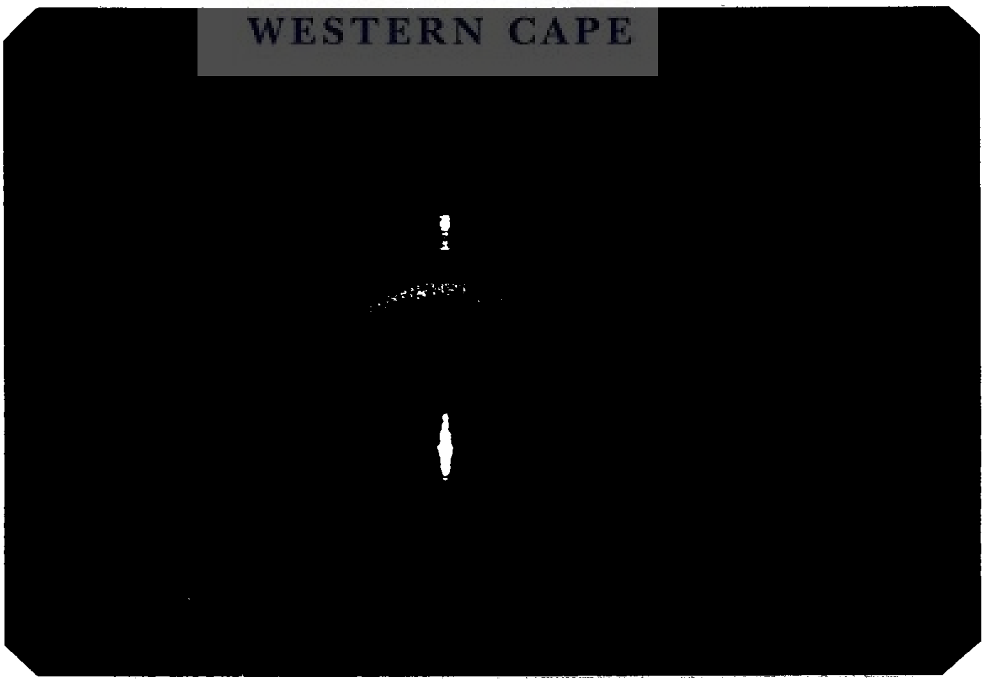


FIG.2. Impression material mould B on glass slab with cotton-backed surgical adhesive tape.

FIG.3. Test block fitted inside impression material mould

FIG.4. Gypsum mould D containing gypsum placed over mould B containing alginate

6,3 METHODS : Phase 1

6,3.1 Procedure for alginate/gypsum combinations

The following description of the actual procedure used closely follows that laid down in ISO 1563 ("the Standard").
For each test, a flat glass plate was covered with cotton-backed surgical adhesive tape, sufficiently large to be a base for the impression material mould (mould B). (see Fig. 2).
The volumetric containers provided with each alginate were used for the dispensing of the quantities recommended by each manufacturer. Distilled water was used throughout, and room temperature was 22 ± 1°C. The alginate and water were hand spatulated for 60 seconds or less according to the manufacturers instructions. Hand spatulation was chosen as it was felt that (a) this is the most commonly used method in clinical practice and (b) it has been shown that mechanical spatulation with an alginator does not by itself guarantee the elimination of air bubbles of significant dimension (Reisbick, Garrett and Smith, 1982). The use of water at temperatures of 3°, 10°, and 20° has been shown to produce impressions that do not appear to differ from each other in accuracy (Harris, 1969). The temperature of the water used throughout was 21 ± 1°C.
The Standard recognises the fact that, despite the smooth surface specified for the test block, some alginates might

stick to it : "If the alginate adheres to the surface of the ruled test block, dust the block with talcum prior to use and blow away any excess powder". It was found that with some of the alginates this was indeed the case, but it was also found that dusting with talcum only exacerbated the problem, and furthermore clogged up the ruled lines. Therefore it was decided to use a layer of saliva on the block to overcome this problem, it also being felt that this might help to simulate clinical conditions. This improved the situation in most cases except that occasionally Colourgel still adhered in parts, and S S White alginate displayed small spots of adhesion. In neither case did the adhesion interfere with the recording of the ruled lines.

Thus, after mixing the alginate it was placed into mould B and slightly overfilled. The test block was then pressed down into the mass of alginate and the assembly immediately placed in a water-bath maintained at 32 ± 1°C and loaded with a 1 kg. weight (see Fig. 5). The temperature of the water-bath is that advised by the Standard, although it has been shown in one study that an alginate attained a temperature in the mouth after four minutes of 28,6 ± 0,4°C (Elborn and Wilson, 1965). Exactly 3 minutes after placement in the water-bath, the assembly was removed and the test block separated from the mould. The alginate surface was rinsed with distilled water and the excess shaken off. Mould D was then placed over mould B and the gypsum prepared.

FIG.5. Test block and impression material mould assemblied (as per Fig. 3), placed in water-bath, and loaded with 1 kg. weight. Background shows some of the test casts.

The gypsum was weighed on a dietetic scale, 50 grams at a time, and distilled water used for the mix. Prior to the actual tests, tests were carried out to determine the minimum amount of distilled water necessary to produce a consistent working mix with the powder as measured on the dietetic scale. The resultant water/powder ratios were those used throughout and are shown in Table III (see page 20). The gypsum was mechanically mixed under vacuum for 15 seconds, then vibrated still under vacuum for a further 5 seconds. (Vac-U-Vester model B, Whip-Mix Corp., U S A). It has been shown that a reduction in porosity of almost 60% is obtained when gypsum is subjected to vacuum treatment (Jorgenson and Kono, 1971).

The mixed gypsum was then poured into mould D under vibration in such a way as to displace any adhering moisture from the surface of the alginate. The gypsum was allowed to harden for exactly 30 minutes, when mould D containing the gypsum cast was separated from the alginate and examined. Three tests for each alginate and gypsum combination were carried out in this manner. The orientation of alginate beneath gypsum is in accordance with findings that poor cast surfaces were obtained when the orientation is with the alginate over the gypsum. (Young, 1965).

6,3.2 Procedure for rubber-based materials

A polyether (Impregum) and a polysulphide (Permlastic Regular) were used in the same manner but with the following exceptions:

(a) the test block was used dry, with no film of saliva ; (b) the assembly was placed in the water-bath for 6 minutes for Impregum and 9 minutes for Permlastic ; (c) the impression surfaces were not rinsed afterwards and were cast dry; and (d) only three of the gypsum products were used, namely Yellow stone, Peach stone, and Vel-Mix.

6.4 EVALUATION OF CASTS

The Standard states that the casts should be observed under low-angle illumination with a magnification of 6 to 12X, and the finest line reproduced over the full length of 25 mm be recorded. The final test result is the finest line reproduced at least twice, resulting from three tests.

In this study, this procedure was followed (using magnification of 10X), but in order to increase discriminatory capability, an evaluation procedure was also adopted, a modification of which has been shown to be useful in a previous study (Morrow et al, 1971). In the present study the 0,050 mm line was evaluated, as it was felt that alginate materials should not be used for crown or inlay impressions, and the Standard requires such materials to reproduce the 0,020 mm line (Class A).

Each cast was placed under a microscope (Zeiss stereomicroscope Model IVb) which has an attachment for a 35 mm S.L.R. camera. The section of the 0,050 mm line judged to have been best reproduced was then photographed. To provide a constant light source, an automatic electronic flash unit (Sunpak auto 170) was used, at a constant distance from, and angle to, the

FIG.6. Test cast on microscope stage, showing constant position of light source (flash unit)

casts (see Fig.6). By using this light source, and 125 ASA black-and-white film (Ilford FP4) it was found that a consistent photograph (magnification approx. X20) could be obtained. The reasons for this procedure were to reduce errors of judgement that might be caused by

(a) evaluators using a microscope for any lengthy period of time;

(b) viewing casts of differing colours and thereby producing different light-reflective effects; and

(c) requiring the evaluators to select a section of the line.

Thus for each alginate/gypsum combination, 3 negatives were made, but as one cast is discarded only 2 prints will result. The film was developed automatically at a commercial photographic laboratory, and the prints made on high-contrast paper. A 10 cm section of the line was marked on the print and each print coded randomly. Evaluators were then asked to score the quality of the line thus marked. Further details of the scoring are discussed later (see page 49).

6,5 METHOD : Phase 2

In order to test the effect of a fixing solution on compatibility, the investigator selected combinations of materials that had failed to reproduce any of the lines on the test block satisfactorily, and subjectively evaluated 10 such combinations as being the worst.

6,5.1 Procedure

These ten combinations were then tested in exactly the same manner as during Phase 1 above, but with the exception that after rinsing the alginate surface with distilled water, a fixing solution of a 2% aqueous solution of potassium sulphate was poured into the mould and left to stand for 5 minutes. After this time the solution was poured off, the excess shaken off, and the gypsum cast as before.
Once again, one cast was rejected, resulting in two photographic prints, which were coded and added to the series of prints resulting from Phase 1.
A further subjective evaluation of the resulting casts showed that very little, if any, improvement occurred in the reproducibility of the lines and quality of the cast surface. It was therefore decided to carry out further tests on different concentrations of potassium sulphate, and also to use another fixing solution which had empirically shown good results in the past, namely alum.

6,6 METHOD : Phase 3

For these tests, 5 of the combinations in Phase 2 were selected, and tested in the same manner, using an 8% aqueous solution of potassium sulphate.
Subjective evaluation once again revealed little improvement, and so a saturated solution (12%) of potassium sulphate was

made up (Potassium sulphate is saturated at 12% at 25°C), and a single combination was tested. As this again revealed no improvement, no more of these combinations were tested.

6,7 METHOD : Phase 4

In order to test the usefulness of alum as a fixing solution, the 5 combinations used in Phase 3 were tested using both a 2% aqueous solution and a saturated (13%) solution (alum saturates at 11.4% at 20°C).

6,8 METHOD : Phase 5

An alginate that in Phase 1 was subjectively evaluated as having displayed a high degree of compatibility with all gypsum products was Blueprint. This was tested with Vel-Mix for all concentrations of both fixing solutions, and with Yellow Stone for all concentrations, with the exception of 8% potassium sulphate.

6.9 NUMBER OF CASTS AND PRINTS

Number of casts:

Phase 1 : 228 (Alginate/Gypsum combinations: 210;
Elastomers/Gypsum combinations: 18)

Phase 2 : 30 (2% K_2SO_4 + Alginate/Gypsum)

Phase 3 : 18 (8% K_2SO_4 + Alginate/Gypsum)

Phase 4 : 30 (2% alum + Alginate/Gypsum: 15;
8% alum + Alginate/Gypsum: 15)

Phase 5 : 27 (Blueprint/Yellow stone: 15;
Blueprint/Vel-Mix: 15)

TOTAL **333**

Number of resultant Prints:

As stated, 2 prints will result from the 3 casts made from each combination of materials.

Phase 1 : 152

Phase 2 : 20

Phase 3 : 12

Phase 4 : 20

Phase 5 : 18

TOTAL **222**

7. RESULTS

7,1 REPRODUCTION OF LINES

All the gypsum products reproduced the 0,050 mm line when tested directly against the test block, but all **failed** to reproduce the 0,020 mm line.

The finest lines recorded, using the criteria in the Standard, are shown in Table V (page 38) for the untreated impressions.

Table V(a) highlights those combinations reproducing the 0,050mm line as the best line reproduced.

Table V(b) highlights those combinations reproducing the 0.075mm line as the best line reproduced.

Table V(c) highlights those combinations failing to reproduce any of the lines.

Table VI (page 42) shows the results obtained for impressions treated with potassium sulphate.

Table VII (page 43) shows the results obtained for impressions treated with alum.

TABLE V Finest line reproduced over 25mm at least twice from three tests, in micrometers

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
Blueprint	50	50	50	50	50	50	50
Colourgel	none	none	none	none	50	none	none
G-C Fast-set Technicol	none	none	none	none	50	75	50
G-C Vericol Aroma	none	none	none	75	50	75	50
Kalginate	50	50	75	75	50	50	50
Kerr Alginate	50	50	50	50	50	50	50
Key-to-Alginate	50	50	50	75	50	50	50
S S White	none	none	none	none	75	none	none
Zelgan Green	none	75	none	none	50	50	50
Zelgan Pink	none	none	none	none	50	none	none

TABLE V(a) Compatible alginate/gypsum combinations, based on the ability to reproduce the 0,050 mm line according to the method used

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
Blueprint	*	*	*	*	*	*	*
Colourgel					*		
G-C Fast-set Technicol					*		*
G-C Vericol Aroma					*		*
Kalginate	*	*			*	*	*
Kerr Alginate	*	*	*	*	*	*	*
Key-to-Alginate	*	*	*		*	*	*
S S White							
Zelgan Green					*	*	*
Zelgan Pink					*		

TABLE V(b) Compatible alginate/gypsum combinations based on the ability to reproduce the 0,075 mm line according to the method used

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
Blueprint							
Colourgel							
G-C Fast-set Technicol						*	
G-C Vericol Aroma				*		*	
Kalginate			*	*			
Kerr Alginate							
Key-to-Alginate				*			
S S White					*		
Zelgan Green		*					
Zelgan Pink							

TABLE V(c) Incompatible alginate/gypsum combinations based on the failure to reproduce any of the lines according to the method used

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
Blueprint							
Colourgel	*	*	*	*		*	*
G-C Fast-set Technicol	*	*	*	*			
G-C Vericol Aroma	*	*	*				
Kalginate							
Kerr Alginate							
Key-to-Alginate							
S S White	*	*	*	*		*	*
Zelgan Green	*		*	*			
Zelgan Pink	*	*	*	*		*	*

TABLE VI Finest line reproduced over 25mm at least twice from three tests, in micrometers, after treatment of the impression with concentrations of potassium sulphate as shown. Parentheses indicate results when no fixing solution was used (from Table V)

2% K_2SO_4 +	E P 1	Yellow stone	Ortho stone	Peach stone	Vel-Mix
Blueprint		50(50)			50(50)
Colourgel		none(none)	none(none)		none(none)
G-C Fast-set Technicol				75(none)	
S S White	none(none)		none(none)	none(none)	
Zelgan Pink	none(none)		none(none)	none(none)	
8% K_2SO_4 +					
Blueprint					50(50)
Colourgel		none(none)			none(none)
G-C Fast-set Technicol				none(none)	
S S White	none(none)				
Zelgan Pink			none(none)		
12% K_2SO_4 +					
Blueprint		75(50)			50(50)
Colourgel		none(none)			

TABLE VII Finest line reproduced over 25mm at least twice from three tests, in micrometers, after treatment of the impressions with concentrations of alum as shown. Parentheses indicate results when no fixing solution was used.

2% ALUM +	E P 1	Yellow stone	Ortho stone	Peach stone	Vel-Mix
Blueprint		none(50)			75(50)
Colourgel		50(none)			75(none)
G-C Fast-set Technicol				50(none)	
S S White	75(none)				
Zelgan Pink			75(none)		
13% ALUM +					
Blueprint		75(50)			50(50)
Colourgel		50(none)			50(none)
G-C Fast-set Technicol				50(none)	
S S White	50(none)				
Zelgan Pink			75(none)		

It can be seen from Tables V that the only alginates to successfully reproduce the 0,050 mm line with all the gypsum products, were **Blueprint** and **Kerr Alginate.** None of the materials were able to reproduce the 0,020 mm line, but then nor were the individual gypsum products.

When the elastomer impression surfaces were viewed under the microscope at the required magnification (X10) it was observed that these materials were **also** unable to reproduce the 0,020 mm line. The casts made from them, though, did show reproduction of the 0,050 mm line.

Table VI shows that, using the criterion of line reproducibility, potassium sulphate has no general significant effect.

However, some specific individual effects can be seen:

Firstly, when Blueprint was treated with the saturated solution, there was a deterioration in the line reproduced with Yellow stone.

Secondly, the improvement shown by the Technicol/Peach stone combination with the 2% solution was reversed when a higher concentration was used.

It can be seen from Table VII that several individual changes were observed:

-2% alum improved the combinations using Colourgel and S S White.

-the saturated solution further improved the Colourgel/Vel-Mix and S S White combinations. This solution also improved the Zelgan Pink and Ortho stone combination.

-the 2% solution had a deteriorating effect on the Blueprint, an effect made worse by using the saturated solution for the Blueprint and Yellow stone combination, but made better for the Blueprint and Vel-Mix combination.

As there were several changes noted, some contradictory, a statistical analysis was carried out using a nonparametric method as follows:

Sign test as applied to Table VII:

Let an improvement in line reproduction = +ve (e.g. none → 75;
none → 50;
75 → 50)

Let a deterioration in line reproduction = -ve (e.g. 50 → 75;
50 → none;
75 → none)

With 2% alum: Number of +ves = 4

Number of -ves = 2

Number of zeros (no change) = 1

With 13% alum: Number of +ves = 5

Number of -ves = 1

Number of zeros = 1

H_o: Null Hypothesis: The median of the differences is zero.

Alternative hypothesis: The median of the differences is positive.

Statistical test: Each result is a matched pair; the sign test is appropriate.

Significance level: Let a = 0.05

Rejection region: All values of x (where x = the number of minuses) whose one-tailed associated probability of occurrence under the null hypothesis is equal to or less than a = 0,05.

Decision: For 2% alum: x = 2, N = 6. The table of one-tailed probabilities under H_o for the binomial test when P = Q = $^1/_2$ shows (Siegel,1956) that for N = 6, an $x \leq 2$ has a probability occurrence of p = 0,344.

For 13% alum: x = 1, N = 6. For N = 6, an $x \leq 1$ has a probability occurrence of p = 0,109.

Both these results lie outside the region of rejection for a = 0,05 and indicates no significant difference.

Thus, using the criterion of line reproducibility, one can conclude that alum has no general overall beneficial effect. This implies, as with potassium sulphate, extrapolation of the results over the range of alginate impression materials. Such a conclusion, however is clearly invalid, as some of the individual results have shown.

7,2 INCREASED DISCRIMINATION - EVALUATION OF PRINTS

7,2.1 Evaluation procedure

Four evaluators were used, the investigator plus three others. All were first tested for variability by first evaluating 10% (22) of the prints, randomly chosen, three times during the course of one day.

Evaluation of the full range of tests took place once on one day, and twice on the next day, giving 2664 assessments. The evaluators were asked to score the tests on the following basis:

Score 1: Line reproduced clearly and sharply over entire length between the marks. This is the best in appearance.

Score 2: Line clear over more than 50% of length
OR Line indistinct over less than 50% of length
OR Line appears to be reproduced well over entire length, but not sharply, but is smooth.

Score 3: Line clear over less than 50% of length
OR Line indistinct over more than 50% of length
OR Line visible over entire length but blemished and rough and/or not sharp.

Score 4: Line not reproduced over entire length; rough, blemished, pitted, etc.
This is the worst in appearance.

Figs. 7 to 10 show examples of prints that were scored in each category.

FIG.7. This print was scored in category 1 in each test by all evaluators.

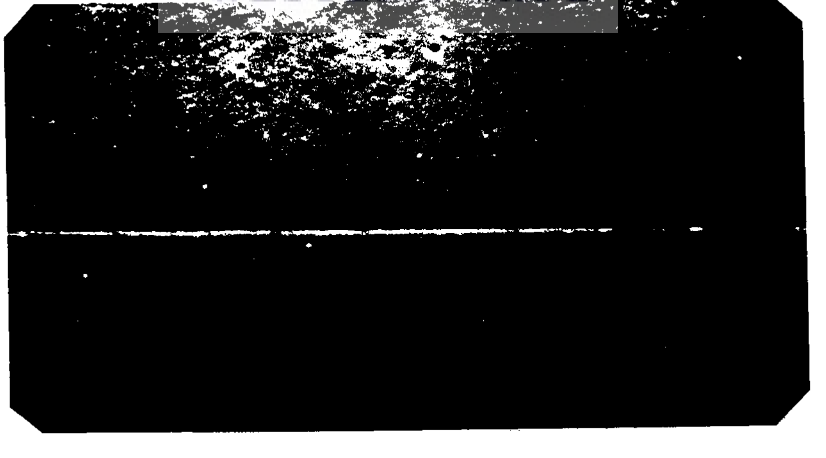


FIG.8. This print was scored in category 2 in each test by all evaluators.

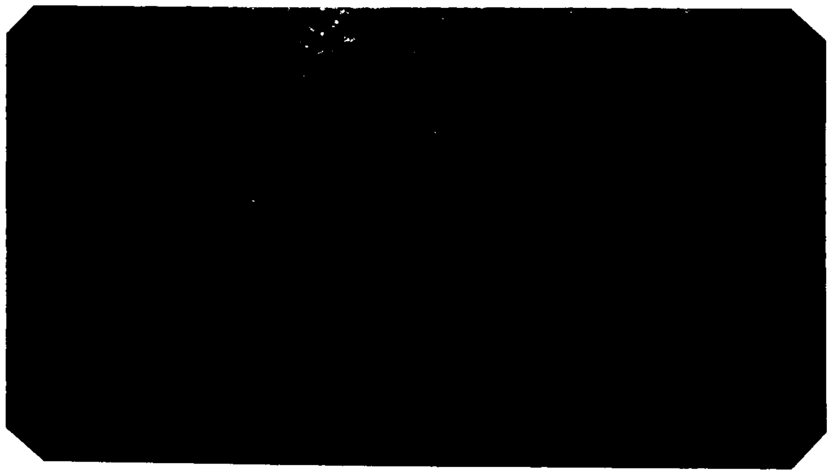


FIG.9. This print was scored in category 3 in each test by all evaluators.

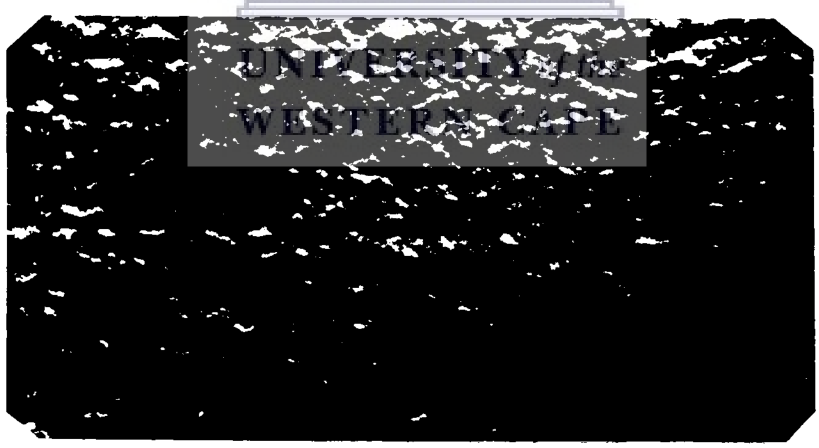


FIG.10. This print was scored in category 4 in each test by all evaluators.

Further examples of prints are shown in the Appendix. (pages Aiii and Aiv).

Of the 80 sets of three scores on the 10% random sample of tests, all were in close agreement. No evaluator differed in his scores by more than one point, and 7 of the 22 tests were given equal scores by each evaluator.

Of the 888 sets of three scores over the full series of tests, it was found that 9 sets differed by more than one point, none being from the same print. These are shown in Table VIII.

When these differing scores were summed and grouped, and compared with the average of the sums of the three scores per combination of the other three evaluators, there was found to be no significant difference ($p \leq 0,001$) in the fact that these scores had a greater spread ($t = 0,67$).

Therefore it was decided that the sums of the three scores per evaluator could be used in the statistical analysis of the data.

TABLE VIII Scores differing by more than one point

COMBINATION ALGINATE/GYPSUM	EVALUATOR	SCORES 1ST	2ND	3RD
2% alum + Colourgel/Yellow stone	2	4	2	2
Kerr Alginate/Peach stone#	3	1	2	3
Kerr Alginate/ 50/50	3	2	4	1
Key-to-Alginate/Peach stone	3	1	3	3
Blueprint/E P 1	4	2	1	3
Blueprint/Yellow stone	4	1	2	3
Kalginate/Yellow stone	4	1	3	3
Kerr Alginate/Ortho stone	4	1	2	3
Kerr Alginate/Peach stone#	4	1	3	3

#Prints from different casts.

7,2.2 Results

The primary source of interest throughout is the interaction between the impression materials and the gypsum products. It would be of concern if the scores obtained from the evaluation procedure were to unduly influence this; if the inter-observer variability was such as to do so, then if would mean that either the scoring procedure was invalid and unrepeatable, or that the evaluators were unusual, or biased, or that some other unknown factor or factors were in force.

Therefore, initially, a three-way analysis of variance was set up using a fixed-effects model.* The summary is shown in Table IX, and the data used are given in the Appendix (page A.ii.). These data are arranged to show the scores per print per combination.

* 1981 version of BMDP2V programme developed at the Health Sciences computing facility, UCLA, which is sponsored by NIH Special Research Resources Group RR-3, copywright (C) 1981 Regents of California, Los Angeles.
Programme run at the Computer Centre, University of Cape Town, by kind permission.

TABLE IX Three-way analysis of variance using fixed-effects model, using the sums of the three scores per evaluator

SOURCE	df	S.S	Mean Squares	F	Tail Prob
Alginates	9	2180,15	242,239	203,68	0,0000
Gypsum	6	559,27	93,212	78,38	0,0000
Evaluators	3	177,04	59,014	49,62	0,0000
Interaction alginates/gypsum	54	618,80	11,459	9,64	0,0000
Interaction alginates/evaluatores	27	69,06	2,558	2,15	0,0011
Interaction gypsum/evaluators	18	20,26	1,125	0,95	0,5229
Interaction alginates/gypsum/evaluators	162	116,39	0,718	0,60	0,9998
Error	280	330,00	1,189		
Totals	559	4074,08			

From Table IX, various effects can be observed:

-The results show very significant F magnitudes for the alginates and gypsum, which indicates that these materials differ markedly between brands; it is logical for the alginates to have such a high significant figure, as these materials differ most in chemical composition; similarly the lower figure for gypsum is indicative of a lesser compositional difference, but its significence confirms that different types of gypsum have been used, from model plasters to the alpha-modified die stones.

-The next significance figure was for the evaluators. This shows that there is an inter-observer effect which must be assessed.

-There is a highly significant effect in the interaction between the alginates and gypsum.

-There is an interesting smaller effect between the alginates and the observers, but no significant effect between gypsum and observers. This is reflective of the high inter-observer score and although significant at the 0,001 level, it is at a much lower level of significance than the higher F numbers in the table. It may be indicative of some difficulty in scoring the prints, as there are difficulties in distinguishing between the middle scores as compared to the extremes. Given that the scoring procedure does not strictly satisfy the requirements for analysis of variance (namely that the observations form a continuous variable, normally distributed), one may postulate that this interaction reflects this property of the method.

It was decided not to investigate this further.

-There is no significance in the three-way interaction between alginates, gypsum, and observers. This observation is influential in assessing the importance of the inter-observer effect, as it means that although there is inter-observer variability, it does not detract from the clear indications of effects between alginates, between gypsum products, and especially in the interactive effect of alginates and gypsum. Thus the alginate and gypsum interaction is consistent across the observers.

Further confirmation that the inter-observer variability will not affect the basic significant interactive effects can be obtained by considering the observers to be a random sample drawn from the set of all possible observers. The fixed-effects model presupposes that effectively there are only four observers, and has shown that they vary between one another; one must assess the effect of repeating the scoring procedure with four different observers where although the same patterns of scoring might arise, there may be different results. The extent of the variability that would be incorporated into such repetitions can be assessed piecemeal by a mixed (random-effects) model, where the observer effect is presumed to be a random one, and the other effects are presumed to be fixed as before. When such an assumption is made, the basis upon which certain effects are considered significant is different: ratios within the three-way table must be considered, not simply ratios against the error. It is then necessary to estimate the various components of this new variability that would appear, and in such a situation, the following variance estimates arise (John, 1971).

For interaction alginate/gypsum/evaluators,	$\sigma^2 = 0$
For interaction gypsum/evaluators,	$\sigma^2 = 0$
For interaction alginate/evaluators,	$\sigma^2 = 0,1$
For error,	$\sigma^2 = 1,02$
For interaction alginate/gypsum,	$\sigma^2 = 1,34$
For gypsum,	$\sigma^2 = 1.15$
For alginates,	$\sigma^2 = 4,28$

The figures reflect the comparative overall contribution of the corresponding components of variance, to the overall variance of the individual data scores (sums).

Thus the same overall conclusions as appeared from the fixed-effects model can be made of the contribution of these components, and hence it is extremely unlikely that the significant effects of interest will be rendered ineffective by inter-observer variability. Furthermore, if the scoring is repeated with other observers, one can expect the findings to be consistent.

One can thus conclude that because the observers can be considered representative and the findings consistent, and because the triple interaction alginate/gypsum/evaluators is not significant, and because of the orthogonal design of the experimental method and its replicative nature,the alginates, gypsums, and their interactions can be considered as statistically independent of the observer effects.

For each alginate and gypsum combination, two prints are scored. The means of the sums of the three scores for the four evaluators will now generate two replicates per combination. The assumptions implicit in an analysis of variance procedure are more nearly satisfied by such (now justifiable) simplification of the data, as by consistently looking at the mean scores, one renders the data more amenable to the assumption of normality; the mean values will be less restricted than the original data values on which the three-way analysis was based.
Hence these scores can now be subjected to a two-way analysis of variance procedure, the alginate and gypsum interaction being the primary source of interest.

The mean scores for the untreated alginate and gypsum combinations are shown in Table X.

TABLE X The two mean values obtained for each combination of alginate and gypsum, from the sum of the three scores for the four evaluators. These replicates were used in the two-way analysis of variance.

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
	3,75	6,00	6,25	5,50	4,00	3,50	7,25
Blueprint	3,75	5,00	4,00	7,00	3,50	4,75	6,50
	12,00	12,00	12,00	11,00	6,25	9,50	9,25
Colourgel	9,75	12,00	12,00	12,00	6,00	7,00	9,00
G-C Fast-set	12,00	12,00	10,75	11,25	5,50	7,00	9,25
Technicol	9,75	10,75	11,25	9,00	8,75	7,50	9,50
	10,75	10,75	10,25	11,25	6,00	8,75	6,25
G-C Vericol Aroma	12,00	11,25	10,50	10,25	5,25	9,75	7,00
	8,25	7,25	9,00	8,50	6,25	7,25	8,50
Kalginate	8,75	6,50	9,50	9,50	6,50	7,25	7,25
	7,00	6,00	5,50	5,25	5,75	5,00	6,25
Kerr Alginate	6,25	6,75	6,25	6,75	7,25	6,00	5,25
	8,25	7,00	9,00	7,75	6,25	6,25	7,50
Key-to-Alginate	7,25	6,50	9,00	7,00	6,75	7,50	8,00
	11,75	12,00	11,25	12,00	9,00	11,75	10,75
S S White	9,00	12,00	12,00	12,00	9,25	12,00	11,25
	11,50	9,25	12,00	12,00	6,00	6,25	6,00
Zelgan Green	12,00	9,50	11,50	10,25	6,25	9,25	6,50
	10,75	12,00	12,00	12,00	11,00	11,75	12,00
Zelgan Pink	11,75	11,00	12,00	12,00	12,00	8,75	11,25

There being two replicates per cell, (Table X), this data can be subjected to a two-way analysis of variance procedure, as the primary source of interest is the interaction between the alginates and the gypsum products:

TABLE X(a) Analysis of Variance applied to the means of the sums of the three scores per evaluator (two replicates per cell).

SOURCE	df	S.S.	Mean Squares	F
Alginates	9	544,1	60.4556	84,47
Gypsum products	6	141,3	23,55	32,9
Interaction alginates/gypsum	54	153,9	2,85	3,98
Error	70	50,1	0,7175	
Total	139	889,4		

As to be expected from the previous discussion, there is a significant interaction between the alginates and gypsum products at $p \leq 0,005$.

The error represents the variance between the measures within the 70 pairs of prints.

The analysis provides cell means ('combination means'), and row and column means ('marginal means'). These are shown in Table XI.

TABLE XI Combination means and Marginal means for untreated alginates and gypsum products

	Combination Means							Marginal means: Alginates
	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50	
Blueprint	3,750	5,50	5,125	6,250	3,750	4,125	6,875	5,054
Colourgel	10,875	12,0	12,0	11,50	6,125	8,250	9,125	9,982
G-C Fast-set Technicol	10,875	11,375	11.0	10,13	7,125	7,250	9,375	9,589
G-C Vericol Aroma	11.375	11,0	10,375	10,750	5,625	9,250	6,625	9,286
Kalginate	8,50	6,875	9,250	9,0	6,875	7,250	7.875	7.875
Kerr Alginate	6,625	6,375	5,875	6,0	6,50	5,50	5,750	6,089
Key-to-Alginate	7,875	6,750	9,0	7,375	6,50	6,875	7,750	7,446
S S White	10,375	12,0	11,625	12,0	9,125	11,875	11,0	11,143
Zelgan Green	11,75	9,375	11,750	11,125	6,125	7,750	6,250	9,161
Zelgan Pink	11,250	11,50	12,0	12,0	11,50	10,250	11,625	11,446
Marginal means: Gypsum	9,325	9,278	9,80	9,613	6,875	7,838	8,225	8,707

Consideration of the marginal means will provide a classification of materials. In order to rank them into statistically disparate groups at the 5% level, a Tukey studentized range value was calculated using

$$q^{a=0,05}_{r,rc(n-1)} \sqrt{\frac{s^2}{cn}} \quad \text{for row means (alginates)}$$

and $$q^{a=0,05}_{c,rc(n-1)} \sqrt{\frac{s^2}{rn}} \quad \text{for column means (gypsum)}$$

where r = the number of rows

c = the number of columns

n = the number of replicates per cell, and

s^2 = the mean square residual error with rc(n-1) degrees of freedom. (Miller, 1966).

This yielded a constant of 0,8885 for the alginates and a constant of 0,6904 for the gypsum.

Applying these constants to the marginal means produces statistically disparate groups as follows:

Gypsum: - Plaster of Paris

- Vel-Mix;
  50/50

- Yellow stone;
  E P 1;
  Peach stone;
  Ortho stone

Alginates: - Blueprint

- Kerr Alginate

- Key-to-Alginate;
  Kalginate;

- Zelgan Green;
  G-C Vericol Aroma;
  G-C Fast-set Technicol;
  Colourgel;

- S S White;
  Zelgan Pink

However, such a classification is based on the assumption that it is logical to expect all alginates and gypsum products to react equally well; but the analysis has shown that there is a significant interaction between alginates and gypsum as well as a difference between brands.

Therefore, attention must be focused on the combination means (Table XI). A low combination mean correlates with a high degree of compatibility, and a high combination mean correlates with a poor compatibility.

The poorest combinations will therefore be those with a combination mean of 12, and the best will have a combination mean of 3.

In order to distinguish statistically between these means, it is necessary to calculate the least significant difference (LSD) at the 5% level between any two combination means. This is done using the formula:

$$\text{LSD for two treatment means} = t^{a/2}_{rc(n-1)} \sqrt{\frac{2 \times s^2}{n}}$$

where r = the number of rows
c = the number of columns
n = the number of replicates per cell
s^2 = the mean square residual error. (Rayner, 1967)

This value computes to the figure 1,6835.

Table XI can now be consulted with this figure in mind in order to determine the statistically significant combination means.

It would now be possible to tabulate the smaller means not differing statistically on the combined data for a given impression material, and the combined data for a given gypsum product.

This has been shown in Tables XII and XIII.

TABLE XII Smaller means (below 7,5) not differing significantly on the combined data for a given alginate

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
Blueprint	3.750	5,50	5,125		3,75	4,125	
Colourgel					6,125		
G-C Fast-set Technicol					7,125	7,250	
G-C Vericol Aroma					5,625		
Kalginate						7,250	
Kerr Alginate	6,25	6,375	5,875	6.0	6,50	5,50	5,750
Key-to-Alginate		6,750		7,375	6,50	6,875	
S S White							
Zelgan Green					6,125		6,250
Zelgan Pink							

TABLE XIII Smaller means (below 7,5) not differing significantly on the combined data for a given gypsum product

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
Blueprint	3.750	5,50	5,125	6,250	3,75	4,125	6,875
Colourgel							
G-C Fast-set Technicol							
G-C Vericol Aroma							6,625
Kalginate							
Kerr Alginate		6,375	5,875	6.0		5,50	5,750
Key-to-Alginate		6,750		7,375			
S S White							
Zelgan Green							
Zelgan Pink							

Similar tables have been drawn up in a previous study (Morrow et al, 1971) but the efficacy of doing so is questionable, as implicit in such a tabulation is the assumption that the impression material or gypsum product is either **preselected,** or that there is none other **available:** such situations are not the basis for selection of appropriate dental materials to be used clinically.

Therefore a more significant ranking would be via statistically disparate **combinations**, at least for those showing low combination means (high compatibility). Such a ranking is shown in Table XIV.

TABLE XIV Ranking of statistically disparate combinations based on the combination means for means below 7.5 (median of possible range 3 to 12)

Blueprint / E P 1
Blueprint / Plaster of Paris
Blueprint / Vel-Mix
Blueprint / Ortho stone
Blueprint / Yellow stone
Kerr Alginate / Vel-Mix
Kerr Alginate / 50/50
Kerr Alginate / Ortho stone
Kerr Alginate / Peach stone
Zelgan Green / Plaster of Paris
Colourgel / Plaster of Paris
Blueprint / Peach stone
Zelgan Green / 50/50
Kerr Alginate / Yellow stone
Kerr Alginate / Plaster of Paris
Key-to-Alginate / Plaster of Paris
G-C Vericol Aroma / 50/50
Kerr Alginate / E P 1
Key-to-Alginate/ Yellow stone
Blueprint / 50/50
Kalginate / Yellow stone
Kalginate / Plaster of Paris
Key-to-Alginate / Vel-Mix
G-C Fast-set Technicol / Plaster of Paris

The two ranked groups shown above are thus the combinations that will give the best detail reproduction and surface compatibility according to the test methods used. They can be represented, without ranking within the groups, as shown in Table XV where *** indicates the combinations of the first group which do not differ statistically from each other, but which do differ statistically from the second group, indicated by *. Again, these do not differ statistically from each other.

TABLE XV Statistically significant smaller combination means (see text)

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
Blueprint	***	*	***	*	***	***	*
Colourgel					*		
G-C Fast-set Technicol					*		
G-C Vericol Aroma							*
Kalginate		*			*		
Kerr Alginate	*	*	*	*	*	*	*
Key-to-Alginate		*			*	*	
S S White							
Zelgan Green					*		*
Zelgan Pink							

7,3 EFFECTS OF SURFACE TREATMENT OF ALGINATES

The five alginates and gypsum products chosen to be used for the assessment of the effects of fixing solutions on compatibility are shown in Table XVI with their untreated combination mean values.

TABLE XVI Combination means of untreated combinations used for surface treatment

	E P 1	Yellow stone	Ortho stone	Peach stone	Vel-Mix
Blueprint		5,50			4,125
Colourgel		12,00	12,00		8,250
G-C Fast-set Technicol				10.125	
S S White	10,375		11,625	12,00	
Zelgan Pink	11,250		12,00	12,00	

7,3.1 Effects of Potassium sulphate

Table XVII shows the combination means obtained from the potassium sulphate-treated casts.

TABLE XVII Potassium sulphate-treated alginates and gypsum products: combination means

$2\%\ K_2SO_4$ +	E P 1	Yellow stone	Ortho stone	Peach stone	Vel-Mix
Blueprint		7,125			8,375
Colourgel		12,0	12,0		11,50
G-C Fast-set Technicol				9,375	
S S White	11,50		12,0	12,0	
Zelgan Pink	12,0		12,0	11,875	
$8\%\ K_2SO_4$ +					
Blueprint					8,0
Colourgel		12,0			12,0
G-C Fast-set Technicol				10,250	
S S White	12,0				
Zelgan Pink			12,0		
$12\%\ K_2SO_4$ +					
Blueprint		5,625			6.125
Colourgel		12.0			

These results were subjected to paired t-test procedures on the differences in scores between untreated casts and treated casts.The results are as follows:

For 2% potassium sulphate:

$t = -2,026$

$df = 11$

$\overline{\Delta} = -0,875$

$S_\Delta = 1,496$

At $p \leq 0,01$ this result is not significant.

For 8% potassium sulphate:

$t = -2,068$

$df = 5$

$\overline{\Delta} = -1,56$

$S_\Delta = 1,848$

At $p \leq 0,01$ this result is not significant.

For 12% potassium sulphate:

$t = -1.099$

$df = 2$

$\overline{\Delta} = -0,71$

$S_\Delta = 1,119$

At $p \leq 0,01$ this result is not significant.

These results would lead to a general conclusion that potassium sulphate is inadequate as a fixing solution at any concentration. However the statistical test itself would not reveal an individual significant result.

In view of the fact that the values for the treated casts were obtained in exactly the same way (and all prints were evaluated in the same batch), then if **individual** comparisons are to be made, one can use the independent estimate of variance taken from the analysis of variance table as an indication of the sort of variance expected between treated and untreated means. Thus any change in a combination mean greater than the least significant difference value 1,6835 (which is consequent upon the variance) is prima facie evidence that that change is significant.

When applied to Table XVII the following combinations showed significant change:

2% and 8%: Blueprint / Vel-Mix
Colourgel / Vel-Mix
12%: Blueprint / Vel-Mix

Unfortunately, the change in each case was for the worse.

Because it was originally expected that an improvement would be seen, four of the alginates used for this treatment phase were ones showing poor compatibility; Blueprint was included to provide a contrast. In case its effects (which were a lack of improvement) could be having an undue influence on the results of the paired t-tests, these were repeated, excluding Blueprint.

The results are as follows:

For 2%: $t = -0,942$

$df = 9$

$\bar{\Delta} = -0,04625$

$S_{\Delta} = 1,4730$

For 8%: $t = -0.833$

$df = 4$

$\bar{\Delta} = -1,099$

$S_{\Delta} = 2,951$

At $p \leq 0,01$ neither of these results are significant.

7,3.2 Effects of Alum

Table XVIII shows the results obtained from the surface treatment of the alginates with 2% and 13% solutions of alum.

These results were also subjected to paired t-test procedures on the differences in scores obtained.
The least significant difference constant was then applied to the individual results, and then once again paired t-tests were applied with the exclusion of Blueprint.

TABLE XVIII Alum-treated alginates and gypsum products: combination means

2% alum +	E P 1	Yellow stone	Ortho stone	Peach stone	Vel-Mix
Blueprint		11,125			8,825
Colourgel		9,375			7,0
G-C Fast-set Technicol				6,875	
S S White	8,750				
Zelgan Pink			12,0		
13% alum +					
Blueprint		7.0			8,0
Colourgel		6,875			7,875
G-C Fast-set Technicol				8,250	
S S White	6,250				
Zelgan Pink			7,750		

The paired t-test results for all combinations are as follows:

For 2% alum: $t = -0{,}169$ For 13%: $t = 1.175$

$df = 6$ $df = 6$

$\bar{\Delta} = -0{,}226$ $\bar{\Delta} = 1{,}483$

$S_{\Delta} = 3{,}537$ $S_{\Delta} = 3{,}338$

At $p \leq 0{,}01$ these results are not significant.

Application of the least significant difference revealed that the changes to the following combinations were significant:

For 2% alum:

Improved (and ranked): G-C Technicol / Peach stone

Colourgel / Yellow stone

S S White / E P 1

Made worse (and ranked): Blueprint / Yellow stone

Blueprint / Vel-Mix

For 13% alum:

Improved (and ranked): Colourgel / Yellow stone

Zelgan Pink / Ortho stone

S S White / E P 1

Made worse: Blueprint / Vel-Mix

Examples of prints of some of these combinations are given in the Appendix (pages Av and Avi).

The paired t-test results excluding the Blueprint combinations are as follows:

For 2% alum:	$t = 1{,}181$	For 13%: $t = 2{,}903$
	$df = 4$	$df = 4$
	$\overline{\Delta} = 1{,}81$	$\overline{\Delta} = 3{,}15$
	$S_{\Delta} = 1{,}258$	$S_{\Delta} = 2{,}170$

At $p \leq 0{,}01$ these results are not significant, but at $p \leq 0{,}05$, the result for the 13% solution is significant.

Thus one must again conclude that alum has no overall general effect, but it can produce a significant change with certain materials. Unfortunately, this change can be in the wrong direction as shown by the reaction with the Blueprint combinations; however the saturated solution seems to confer a significant benefit on the remaining alginates tested.

8 DISCUSSION

An alginate's compatibility with gypsum and its capacity to record details and impart these to a gypsum cast, form one of the requirements for certification of alginate materials under various Standards. It is these qualities only that have been looked at in this study.

Alginate impression materials are used for a wide variety of purposes, from producing diagnostic casts to producing casts on which accurately fitting cast metal frameworks for removable prostheses will be constructed, to, more recently, the use in combination with a reversible hydrocolloid in crown and inlay fabrication. Thus their accuracy and surface detail reproduction and quality are of great importance.

The International Standard ISO 1563-1978(E) has been accepted by 21 member countries, and recognises the fact that alginates require classification into further groups other than the previously-recognised classification according to the setting-time. It has retained the latter, allowing specification as Type I or Type II and has innovated three Classes according to the following table:

Characteristic	Class A	Class B	Class C
Viscosity: diameter of disc,mm	≥ 33	27 to 36	<30
Detail reproduction: width of line reproduced,mm	0,020	0,050	0,075
Permanent deformation,%	≤ 3	≤ 5	≤ 7

The first part of this study closely follows the assessment criteria laid down for detail reproduction, and the results are summarised in Tables V to V(c) (pages 38 to 41). They show that none of the combinations tested could reproduce the 0,020 mm line. However, when two elastomeric impression materials commonly used for crown and inlay impression techniques were tested in the same manner, these too failed to reproduce the 0,020 mm line. Furthermore, when the gypsum products themselves were placed against the test block, they also failed to reproduce the 0,020 mm line. This would seem to cast doubt on the efficacy of including a Class of alginates "suitable for crown and inlay impressions".

If one now considers the remaining two classes, the results show that 34 out of the 70 untreated combinations were able to reproduce the 0,050 mm line. This involved 9 of the alginates and all of the gypsum products. The Standard specifies that for Class B alginate at least one brand of alpha modified gypsum (characterised by a water/powder ratio of about 0,23) and two brands of alpha gypsum (characterised by a water/powder ratio of about 0,3) shall be recommended.

On this basis, then, from the results shown in Table V(b) (page 40) the following alginates would fall into Class B:

Blueprint

Kalginate

Kerr Alginate

Key-to-Alginate

(This, of course assumes that only those gypsum products used are available as easily as are the alginates).
Consideration of the recording of the 0,075 mm line places alginates into Class C provided they react with two brands of alpha gypsum. Reference to Table V(b) shows that only 8 of the 70 combinations reproduced the 0,075 mm line, involving 6 of the alginates and 5 of the gypsum products. Strictly speaking, none of these alginates fulfill the requirement, but G-C Vericol Aroma combined with two alpha modified gypsums, and Kalginate with one alpha modified gypsum and one alpha gypsum (assuming Kerr Ortho stone to be an alpha gypsum).
Reference to Table V(c) (page 41) reveals 28 combinations that lie outside the requirements, involving 6 of the alginates and 6 of the gypsum products.

Previous workers, notably Morrow and colleagues (1971) had noted that all alginates tested were able to reproduce a 0,075 mm groove satisfactorily according to the A D A 18 specification, and hence devised more strict methods of testing. This study has done the same, with the aim of finding superior combinations of alginate and gypsum.

The results show that it is possible to concentrate attention on the combination means obtained, and to group those combinations showing the best compatibility, as given in Tables XIV and XV. Explanations have been given as to why the marginal means should not be used as a classification (page 62) as was used by Öwall and Nilner (1973), and also as to why combined data per alginate or per gypsum should also not be used (page 66) as given by Morrow _et al_ (1971).

That the methods used here have shown a refined discriminatory capacity can be seen by reference to Table V(a) showing those combinations that reproduced the 0,050 mm line, and comparing it with Table XV showing the best combinations according to combination mean scores. Statistical analysis also showed that it is likely that the procedures adopted will be repeatable, and that similar results should be obtained.

Tables V(a) and XV have been reproduced on the next two pages.

TABLE V(a) Compatible alginate/gypsum combinations, based on the ability to reproduce the 0,050 mm line according to the method used

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
Blueprint	*	*	*	*	*	*	*
Colourgel					*		
G-C Fast-set Technicol					*		*
G-C Vericol Aroma					*		*
Kalginate	*	*			*	*	*
Kerr Alginate	*	*	*	*	*	*	*
Key-to-Alginate	*	*	*		*	*	*
S S White							
Zelgan Green					*	*	*
Zelgan Pink					*		

TABLE XV Statistically significant smaller combination means

	E P 1	Yellow stone	Ortho stone	Peach stone	Plaster of Paris	Vel-Mix	50/50
Blueprint	***	*	***	*	***	***	*
Colourgel					*		
G-C Fast-set Technicol					*		
G-C Vericol Aroma							*
Kalginate		*			*		
Kerr Alginate	*	*	*	*	*	*	*
Key-to-Alginate		*			*	*	
S S White							
Zelgan Green					*		*
Zelgan Pink							

There are therefore grounds for considering that the requirements laid down by the I S O Standard could be modified. Firstly, it seems that reproduction of the 0,020 mm line may be too fine a test. Secondly, the semantics used for evaluation are imprecise: the Standard's relevant phrases are "impart a smooth surface to" and "record the finest line reproduced". Certainly there must be a subjective interpretation, but this study has shown that there are ways of increasing the refinement of a subjective evaluation, and statistical analysis reveals this to be efficacious.

When alginates were first developed, fixing solutions were recommended, but it was not long before the manufacturers claimed to have done away with the need for surface treatment (see section 3) and now none of the alginates tested have recommendations for the use of fixing solutions, despite the fact that studies such as this show up basic incompatibilities. It is, of course, extremely difficult to discover the mechanisms involved in an incompatible reaction, but the nature of the colloid itself would seem to be the main culprit. (Although it is interesting to note that the surface teatment with potassium sulphate consistently affected the same gypsum, with two different alginates.)

This study did not test all combinations with fixing solutions, but used only certain selected ones. Very contradictory results were obtained, but as explained in the results, it is possible with the analyses used in this study to discover certain significant individual changes. Thus the improvements in the combination means of some of the alum-treated casts would elevate them into the classification as given for untreated casts (Table XV). None came close to being included in the '3-star' group, but the following combinations would find inclusion in the 'one-star' group:

13% alum + S S White / E P 1

13% alum + Colourgel / Yellow stone

2% alum + G-C Fast-set Technicol / Peach stone

When compared to the results obtained in terms of line reproduction only, once again the refinement of the methods used in this study is shown: of the 5 improvements with alum according to line reproduction, only 3 were subsequently shown to be significant in each group of 2%- and 13%-treated materials.

Thus it is possible to improve certain combinations by surface treatment with certain fixing solutions, but the results overall are rather alarming, for two reasons:

Firstly, the potassium sulphate-treated alginates showed some significant changes for the **worse,** as did the alum solutions when used with an alginate showing a high degree of compatibility (Blueprint). Thus one can by no means state that if an incompatibility exists it can be improved by fixing solutions - just which fixing solution and what concentration must be discovered.

Secondly, the most significant improvements in the treated alginates were with a saturated solution of alum; no studies

have been carried out as to whether this will cause any dimensional change in the alginate itself, nor over what period of time immersion in the solution is ideal.
It therefore seems that, when there **are** compatible combinations of alginate and gypsum materials available, it would be foolish to risk trying to improve an incompatible combination.

Finally it is worth noting that the figures for the '3-star'group of combinations compare very favouably with the combination means for the elastomeric materials, which would fall under this group, with the exception of the Permlastic / Peach stone combination which would be in the 'one-star' group. (These means are recorded in the appendix).

9 CONCLUSIONS

1. This study has considered only the compatibility of alginate impression materials to gypsum, and detail reproduction.
2. A refinement in the subjective evaluation of surface characteristics and detail reproduction has been used and shown to be effective.
3. Different brands of alginate differ in their ability to react with gypsum products, and vice-versa.
4. There are many combinations of alginate and gypsum as tested in this study that are incompatible.
5. Those combinations that are significantly more compatible should be considered in chosing a material for clinical use, bearing in mind that this study has only tested one aspect of many requirements for an adequate material.
6. The most compatible combinations were all produced by the alginate Blueprint.
7. The use of fixing solutions is of dubious value.
8. It is recommended that manufacturers pay more strict adherence to the requirements of the ISO Standard, in respect of the requirement governing the availability and recommendation of suitable compatible gypsum products.
9. Consideration should be given to modification of the ISO Standard to be more realistic in its demands, and more discriminating in its evaluation procedures.

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APPENDIX

Combination means of Impregum and Permlastic

	Yellow stone	Peach stone	Vel-Mix
Impregum	3,250	4,375	4,250
Permlastic	5,375	5,750	5,0

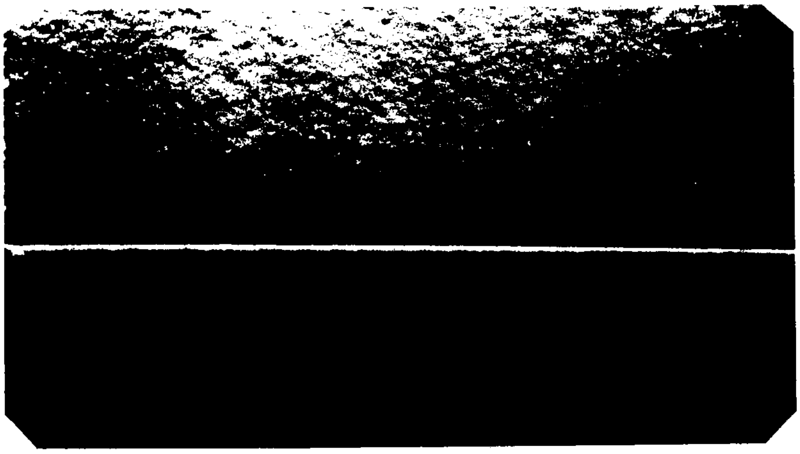

FIG.11. Blueprint and Plaster of Paris

Mean score: 3,5.

FIG.12. Kerr Alginate and Peach stone.

Mean score: 6,0.

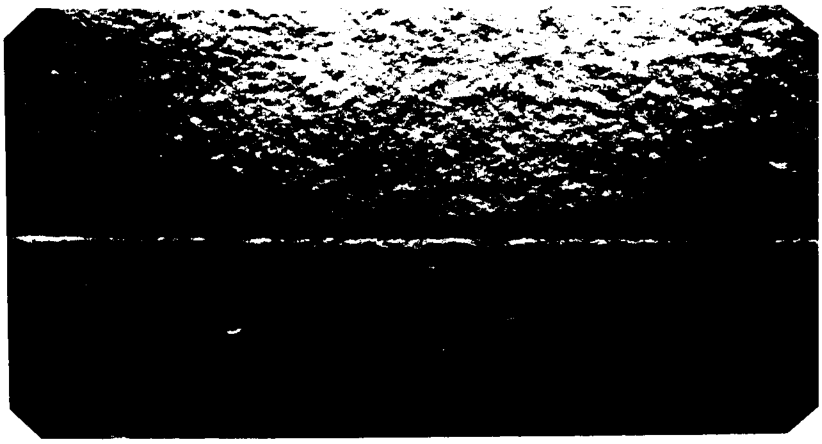

FIG.13. Key-to-Alginate and Ortho stone

Mean score: 9,0.

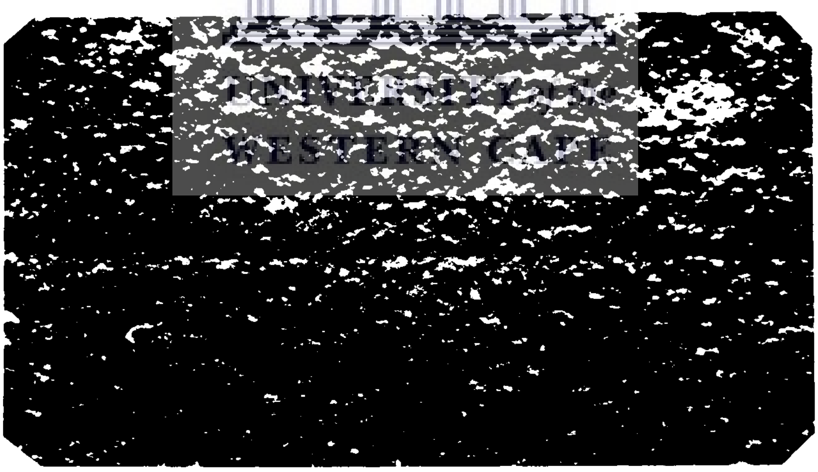

FIG.14. S S White and Peach stone

Mean score: 12,0

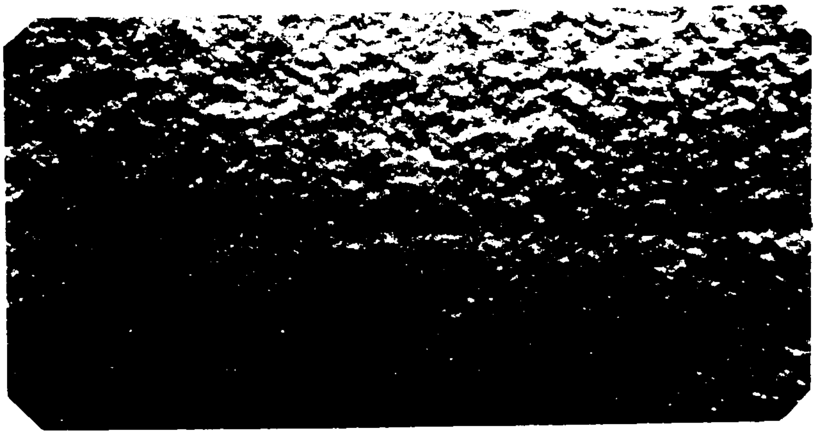

FIG.15. Coloured and Yellow stone

Mean score: 12,0

FIG.16. 13% alum + Colourgel and Yellow stone

Mean score: 6,0

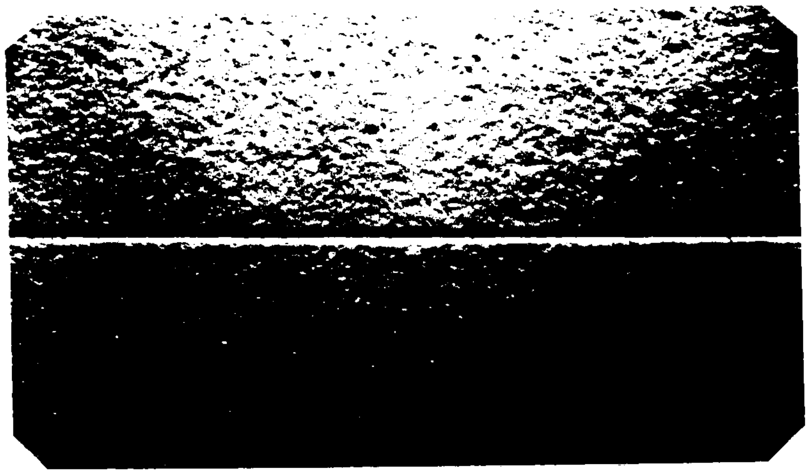

FIG.17. Blueprint and Vel-Mix

Mean score: 3,5

FIG.18. 13% alum + Blueprint and Vel-Mix

Mean score: 8,0

SUMMARY

An irreversible hydrocolloid's (alginate's) compatibility with gypsum and its capacity to record details and impart these to a gypsum cast, form one of the requirements for certification of alginate materials under various Standards. It is these qualities only that have been looked at in this study.
The method used closely followed that laid down by International Standard ISO 1563-1978(E) for alginate impression materials. Ten alginates and seven gypsum products were tested. Using the criteria specified by this Standard, it was found that none of the materials tested were able to record the finest (0.020 mm) line on the test block. However, two elastomeric impression materials tested in the same manner also failed to reproduce this line, as did all the gypsum products when tested directly against the block. These findings cast some doubt on the efficacy of utilising such a fine line in the classification of these materials.
Only 34 of the 70 possible combinations were able to reproduce the 0,050 mm line. 8 combinations reproduced the 0,075 mm line as the finest line, and the remainder (38) failed to record any of the lines.
In order to distinguish between, and to classify the compatible combinations, and in order to provide confirmation or otherwise that line reproduction is a sufficient requirement *per se*, a refinement was introduced.

This was based on a similar procedure described by Morrow et al (1971) but differed in several respects. By photographing the gypsum casts through a stereomicroscope at constant magnification and using a constant light source, it was possible to produce a consistent photomicrograph. The gypsum casts were photographed with black-and-white film, and high-contrast prints obtained of the best-reproduced section of the 0,050 mm line. These prints were then subjected to an evaluation procedure using four evaluators who gave a score to the quality of reproduction of the line on a rating scale of 1 to 4. All prints were scored three times by each evaluator, and the sums of these three scores were subjected to statistical analysis.

The statistical analysis showed this procedure to be consistent, and that it could be expected to be repeatable. On the basis of this analysis, it was found that one alginate was clearly superior to all others, and that it was possibe to distinguish a further group of combinations within the group that reproduced the 0,050 mm line.

Some of the alginate materials were treated with fixing solutions of varying concentrations of potassium sulphate and alum. The results obtained were varied, sometimes producing marked improvement, sometimes deterioration in the surface quality of the subsequent gypsum casts. None of the treated materials could be improved to the extent of equating them with the best of the naturally compatible combinations.

Finally it is recommended that manufacturers pay more strict adherence to the requirements of the ISO Standard with regard to the availability and recommendation of suitable compatible gypsum products, and also that perhaps the actual Standard should be modified to be more realistic in its demands, and more discriminatory in its evaluation procedure.